A Novel Infrared Touch Sensing Using K-Nearest Neighbor Algorithm

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Abstract—Production and usage of touch sensing has attracted much attention, nevertheless, the current touch screen systems highly suffer from the dependency on the platform material. To overcome this drawback, here, a novel method is proposed by considering the infrared transmitters and receivers sensors instead of the piezoelectric sensors. In this way, the transformed platform works based on employing $K$-nearest neighbor (KNN) in conjunction with the spatial-temporal windowing to increase the sensitivity and accuracy of the detecting the finger place on the screen. To verify the proposed approach, the necessary hardware was set up. To test the hardware, the platform is locally segmented (e.g. like a grid) into a $7 \times 8$ table and 50 persons with different finger size were participated. Experimental results show the superior efficiency of the proposed method compare to the conventional methods.

Touch sensing; $K$-nearest neighbor (KNN) algorithm; Infrared sensors; pattern recognition; piezoelectric sensors.

I. INTRODUCTION

Nowadays, most of the versatile applicable devices such as laptops, tablets, game play consults and mobiles use the touch sensing platform and the technology of these platforms are increasingly and rapidly developing [1-2]. In this way, several companies and commercial institutes begin to produce and develop these devices. On the other hand, each research team has presented a patent or special technology for these apparatus. Some research were conducted to utilize an array of sensors with a specific type (e.g. piezoelectric) [3-5], and some tried to acquire the data using the resistance or capacitor sensors (e.g. mobiles and tablets) in the form of a matrix they have to transform the flagged points into the commands with a very short time to be usable in a real time manner [6-7]. Each of the mentioned study has some shortcomings in terms of high dependency on the voltage and current levels. The large number of sensors with lo senility. In contrast, using a few number of transducers lead to construct the device with a smaller size and lower price [8-10]. Recently, there is a growing interest in using image processing based technologies as intelligent tools which need only a simple camera and FTIR (Frustrated Total Internal Reflection) technology [11]. The Piezoelectric sensors which use the waves’ interactions are vastly utilized in the last decade. This technology calculates the delay time caused by the collision of wave and panel or computing the cross correlation between the received waves and the last measured pattern [12-13]. One of the successful approaches in this field is Liu’s [14] method that uses $K$-Nearest Neighbor (KNN) algorithm for localizing the finger in the touch surface. In this paper we first try to describe Liu’s methods and explain the flaw of the Liu’s hardware platform. Then, its hardware problem is explained and propose a new platform based on Infrared sensor. Finally, we propose a new method for better localizing of the finger point base on our infrared platform to compare the the proposed method with the Liu’s method, both are applied to this proposed platform then, we show the superiority of our method in term of better localization [14-15].

The rest of this paper organized as follows. Section2 describes the conventional method along with the proposed method. Section 3 presents the experimental results. Section 4 discusses the advantages and disadvantages of the experimental results and concludes the some future researches.

II. MATERIALS AND METHODS

This section describes the conventional methods and their challenges. Then, the proposed method is presented in some detail.

A. Liu’s Method:

In the Liu’s platform[15], four Piezoelectric sensors (2 emitter and 2 receiver sensors) are used to send excitation signal from a side of panel to other front size and then the reflection signals is received from the receivers as shown in the “Fig.1”.

Figure 1. Liu’s method platform [15]
By putting each typical finger on the platform, an impairment is made on the output signals. The platform is segmented into 32*36 points based on this method. Then an artificial finger is used to extract data from the receiver and save it as a data set. The FFT of the signal is computed and its results is saved as a reference elements bank (in this way, the signal’s period and the number of data received from the receiver is determined based on the surface material). Finally, in the test step, a finger is placed on the platform and the data is received, the FFT is computed and then the Manhattan distance between the new FFT of signal and all of FFT signals that save as a data set is computed then the position \((x, y)\) of the nearest values is assumed as estimated finger position. This method is shown in the “Fig2” \[14\].

B. Liu’s method problems

There are several problems in the designed touch pad using Liu methods, some are explained in the following:
- Dependency on the material platform: as mentioned earlier, the platform surface physical parameters must be determined for computing input signal frequencies and sampling rate. This these parameters is obtained from the material and the physical properties of the touch platform.
- Low process speed in sampling rate: the finger position cannot be calculated until all the signals is received.
- Environment noise interference: The PIZO sensors is sensitive to the environmental noise.

In this problem “dependency of material platforms” is more important than the others, because the surface parameters are changed by time and the environment properties. Then we try to solve this problem here.

C. Propose a new platform

Since the usage of the PIZO sensors lead to these problems, therefore we utilize the Infrared sensors instead of PIZO. There are many different type of such sensors (“Fig 3.a” was shows two kinds of such sensors). Here a new platform was
designed and implemented using two parallel array of sensors consisting of 8 sensors in each side to send and received infrared wave (we assume the right side contain emitter sensors and the left side contain receiver sensors). That is shown in the “Fig 3.b” and a change is detected as soon as a finger is placed on the surface “Fig 3.c”.

III. EXPERIMENTAL RESULTS

A. Implementation Liu’s method in the new platform

As mentioned before, in the Liu’s method a signal is created from the surface, then we need to know the surface parameters to update data samples. In our approach, there is no need to work out some frequency range to apply to the inputs. Therefore, the calculations will be must simpler and faster. This will also us to ignore the surface properties. The “Fig4” shows the data adapted from sensors.

In this approach, one can an get more data from new platform than the Liu’s platform model. According to the Liu’s method, a data set bank (we call it “reference data” here) must be created that is used in the test step. After getting sample data of a specific position, we have more than one data points at each sampling. At this stage, we must select one of the data points as a reference data for this point (a possible position for finger location in the platform). We propose 7 methods for selecting the reference data from the received data for each of the finger positions (here we assume 7*8=56 point in the surface platform).mean, mode, median, maximum and minimum of data or via a random criteria. We applied these choices the training data and the result is shown in the “Table 1”.

Besides, we also used some other famous distance based criteria instead of Manhattan distance and compare the results. The result shown Manhattan distance and median method for computing the reference data have better accuracy than the others. The results show that though the accuracy was 99% in the Liu’s platform, the accuracy has been reduced to 69.7% on our platform. Hence, we propose a new method for increasing this accuracy in the next section. Note that we use have Liu’s method for computing accuracy in the test step (That means, Liu put a finger in the center of platform then get data from receiver sensors, this data were test data.)

B. Propose a novel method in this new platform

Liu uses only one sample as reference data while we can use more number of data in the references data for each class (each of the finger position). For example if we have 56 classes (7*8) then there are only 56 reference data (for each class). Never the less we may use two, three or more data in our reference data for each class. We know that the reference data can be more than one in each class at the One-Nearest Neighbor so we increase the reference data size (data that imported in each class) from 1 to 50 data in each class. Fig.5 shown the change of number of data in each of class and its effective on the result accuracy.

As one can see in the “Fig5” the accuracy of the algorithm is increased during adding more samples. But this question arises that if we want to select two, three or
more data as reference data for each class then, how to select data from “training data” as “reference data” for a specific class? The following method is proposed to selection more than one data in each class:

All the data from the training data for every class is divided to \( r \) separate parts, then median of the data is computed for each one. Clearly, this method considers all the data uniformly. For example if we have 57 classes (7*8=56 points on the touch surface as activated class plus one that is: there is no finger on the surface as deactivated class) and \( r \) reference data for each class, then the number of data that must be used in test step are equal to \( r*57 \) (“Fig.6” shows this method schematically). According to “fig.5”, it is realized that by increasingly data in a class, the accuracy values is increased by growing \( r \)-value. Furthermore, after \( r=50 \) the rate of the growth is very slow. (Therefore we assume \( r = 50 \) here in this paper).

On the other hand, one of the changeable parameters in the K-Nearest Nabors algorithm is the \( k \)-value. In this paper we also change and analyze this parameter. “Fig.7” describes the results on the accuracy value. By growing \( k \)-value, the result accuracies are decreased during change of the reference data size, whereas the accuracy value closes to 50% (random gust). So we assume \( k = 1 \) or \( k = 2 \) for our entire algorithm that proposed here. As you can see, in fig5, the accuracy value is 95.5% in this method that is lower than the Liu’s method, (Remember that the Liu’s method accuracy was 99%), so we use a simple windowing method to increase accuracy value as following

C. Windowing method in data sequence

As mentioned, the sampling rate is very highly in this platform, so we can use previous data to increase performance, therefore we change data sampling rate to 200 samples per second, also the eye process time is 40 samples per second (Note that the image process rate in humanoid eye is 40 images per second [16]). We can assume 5 recent received data as a window and implement our algorithm on them, then according to voting method, select the most repeated element as an output class. Fig.8 showed this method using a diagram.

![Windowing method in data sequence, last 5 time sequence is used to decision making](image)

On the others, we implement a hardware can only able to save received data in its memory. We used saved data in our hardware memory after sampling. So, we cannot use our hardware and we have to estimate our windowing method accuracy mathematically. On the other hand, all the received data can be segmented to two category (similar and not similar), Then we use binomial distribution to compute accuracy of presented windowing method. According to this method, Equation (1) is used for computing accuracy of our windowing method.

\[
(q + p)^n = \sum_{x=0}^{n} \binom{n}{x} p^x q^{n-x} \tag{1}
\]

Here \( q \) is probability of the correct decision (similar classes), \( p \) is probability of the incorrect decision (not similar class), \( n \) is number of experiment and \( x \) is number of experiment that is correct recognized. However, by applying (1) on the windowing method, accuracy value is computed as following:

\[
\text{The windowing accuracy} = \sum_{x=2}^{5} \binom{n}{x} (0.95)^x (0.05)^{n-x} = 0.9988 \tag{2}
\]

We assume a kind of voting here that selects a class with three or more repetition in the last 5 received data. Equation (2) shows accuracy value using this method. As you can see, the accuracy of this method has grown to 99.88%. This is upper than the Liu’s method accuracy (Liu’s method accuracy is 99.5%).

IV. CONCLUSION AND FUTURE WORKS

Using the PIZO sensors casus that we dependence to the platform hardware in the Liu’s method, so we propose a new platform that it used Infrared sensors instead of PIZO sensors. On the other hand, Liu’s method has very low performance in this platform after implementing this method in novel platform, therefore, we try to design a new method based on the Liu’s method(improve it) to increase the performance of it. Results shown that the new method have more performance Compared with Liu’s method (99.88% accuracy vs. 90.5% accuracy).
As mentioned, we create a data set at the first time and apply our method on this data set, so we need a large memory to store data. On the other hand, almost, microcontrollers have very small memory then using an extra memory is not affordable. Therefore, using some other algorithms that used lower memory is very suitable for future works.

REFERENCES


